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THE USE OF DIGITAL STEREO PHOTOGRAMMETRIC METHODS IN HISTORICAL PHOTO ANALYSIS

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ABSTRACT

A historical, temporal photo interpretation method is presented for combining the use of a current digital stereo photogrammetric system with manual photo interpretation techniques. The U.S. Army Topographic Engineering Center was tasked to provide products showing the current 3-dimensional position of certain features present on a 1918 photo mosaic. This mosaic is over a former chemical munitions test area in Washington, D.C.. In order to provide this data, aerial photography from 1918, 1927, 1991 and 1993 was used in the process. This paper will discuss the front end research and collection of textual and photographic data, the manual photo interpretation process, the photogrammetric process and its accuracies, the problems encountered, the digital mapping process and the final products.

INTRODUCTION

In January 1993, construction at a residential building site in the Spring Valley area of Washington, D.C. uncovered some World War I era munitions. This site, and its surrounding area, was part of a chemical weapons development and testing station established by the Bureau of Mines and the War Department in 1917 (see Figure 1). The main development facilities of the station were on the grounds of The American University, called Camp A.U. by the War Department. An adjacent 150 acres were leased to the War Department for the testing of chemicals and munitions developed at the Camp A.U. site (EPA, 1986). A site on this formerly leased property is where the munitions were uncovered in January 1993. The U.S. Army Corps of Engineers' Baltimore District requested that the Corps' Topographic Engineering Center (TEC) in Fort Belvoir, Virginia provide assistance in the placement of historical features onto the current landscape of Spring Valley. A digital photogrammetric workstation was used to create a current 3-dimensional photo model of the area. This technology proved to be beneficial for merging disparate, temporal information into a data set that was useful for historical analysis.

RESEARCH

In 1986 the Environmental Protection Agency produced a historical photo analysis over this area (EPA, 1986). This report cited four aerial photo source dates: 1918, 1927,

REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave blank*)

2. REPORT DATE
1/94

3. REPORT TYPE AND DATES COVERED
Scientific Paper

4. TITLE AND SUBTITLE
The Use of Digital Stereo Photogrammetric Methods in Historical Photo Analysis

5. FUNDING NUMBERS

6. AUTHOR(S)
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U.S. Topographic Engineering Center
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Alexandria, VA 22310, 3864

8. PERFORMING ORGANIZATION REPORT NUMBER
R-207

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approve for public release:
distribution is unlimited.

12b. DISTRIBUTION CODE

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14. SUBJECT TERMS
digital stereo photogrammetric system, photogrammetric process, digital mapping

15. NUMBER OF PAGES
10

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
unclassified	unclassified	unclassified	

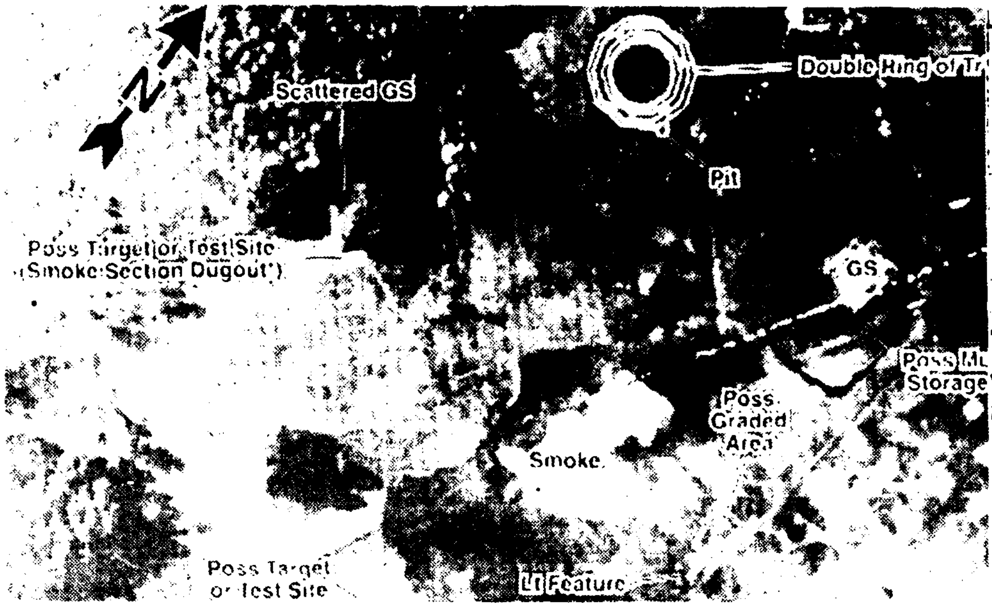

Figure 1. Portion of 1918 aerial photo mosaic over site.

1937 and 1982. TEC received copies of the 1918 photo from the 1986 EPA study and from The American University. The 1918 photo is an uncontrolled, black and white mosaic, at a scale of 1:3,200. TEC's Research Institute, Remote Sensing Division, set out to acquire early through late date, stereo, aerial photos over the area. The <u>earliest</u> date stereo coverage acquired was 1927 photography. Nine film negatives were purchased. These negatives were derived from paper prints. There were three temporal periods within these nine photos: two flight lines were taken during the same leaf-off period, on the same day, but were taken at different times during that day (about 11 a.m. and 2 p.m.); one flight line was taken during a leaf-on period, apparently during the same year as the other flight lines (per evidence of ground scarring from the digging of a ditch for a water conduit). Two of the flight lines were parallel and another was skewed about 10 degrees. The 1927 photos came from the Cartographic Branch of the National Archives, Washington, D.C.. This was black and white photography, 7"x9" format, approximate scale of 1:10,000, flown by the Air Corps (from Bolling Field) for the National Capital Park and Planning Commission. These photos have about 30 percent endlap with 50 to 65 percent sidelap (one set of flight lines has a 20 percent sidelap). No information was found within the Cartographic Branches' records regarding the type of camera used for these photos. A search in the Military Reference Branch of the National Archives revealed information about the approval for the photos to be flown, but no camera data specific to this flight were found. A search of records at the National Air and Space Museum in Washington, D.C., referenced a Fairchild K-3 camera being used by the Air Corps at this period.

Current aerial photography, purchased from a commercial source, consisted of black and white, positive transparencies, taken in March of 1991, at a scale of

1:14,400, with 60 percent endlap (six diapositives were purchased). This photography was found via a search by the Earth Science Information Center at the U.S. Geological Survey in Reston, Virginia. In addition, under a contract for the Corps of Engineers, color photography at a scale of 1:3,600 with 80 percent endlap was flown over the site on 19 January 1993 by a private company. The photos received were color transparencies. These photos showed the present status of development over the areas of concern.

INITIAL PRODUCTS

Until a photogrammetric model of the site could be developed, a number of initial graphic products were produced. This was done to provide a quick, historical, assessment of the site where the munitions were found and its surrounding area. These products were produced by TEC's Terrain Analysis Center for the Corps' Baltimore District that was operating on location at the Spring Valley site. The methods used for positioning of historical features on current map and photo products were accomplished through manual photo interpretation techniques (identification of features by tone, pattern, size, orientation and texture for example) and by rescaling disparate source materials. Figure 2 is an example of one of these products.

Figure 2. Interim product over Spring Valley site.

A wide variety of sources were used to provide the Corps' Baltimore District with initial products about the site situation. These sources included aerial photographs, maps, publications, memos, reports, and official documents detailing events at Camp Leach and Camp American University.

Aerial photographic sources used included the 1918, 1927, 1991 and 1993 photos. The 1918 mosaic showed most of the areas of the Corps concern. The 1927 photos contain relic feature evidence for some areas on the 1918 mosaic (see

Figure 3).

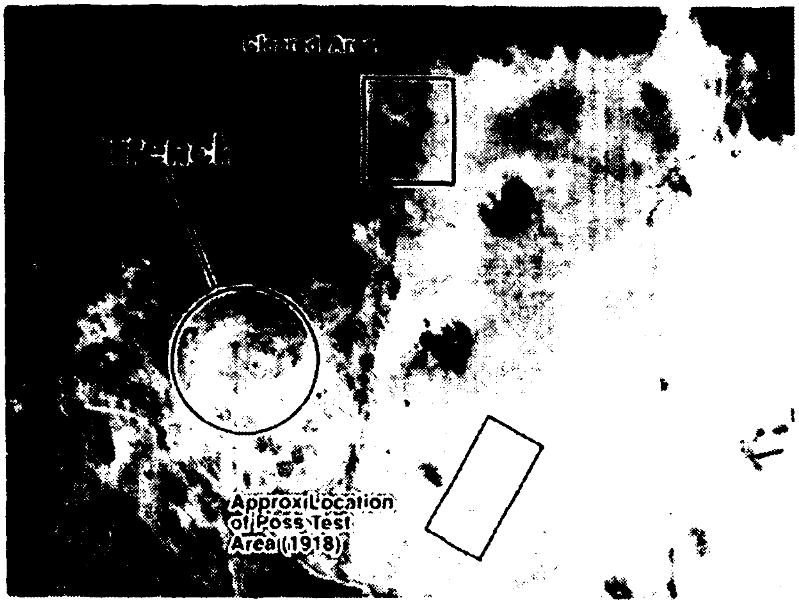

Figure 3. Portion of 1927 photo over Spring Valley site.

Map sources used included topographic maps produced by the United States Geological Survey in 1917, 1945 and 1985. Maps of Camp American University and Camp Leach were used to identify features that were present on the 1918 mosaic as well as some features that fell outside of the mosaic coverage. Blue prints of District of Columbia water and sewer locations were used to identify possible changes in elevation over time, and to identify features on the 1927 photography.

Text sources included official memos, reports, and information papers about Camp Leach and Camp American University. These sources provided information about events and specific features that occurred at the site during and after the First World War.

The aforementioned materials were obtained, by various sources, from The American University, the National Archives in Washington, D.C., the Corps of Engineers' Baltimore District and the Washington, D.C. Department of Public Works.

Products from the Terrain Analysis Center were used as briefing tools, working copies for specific tasks, and to provide information about various concerns. The following are examples of these products: plat maps and subdivision maps were merged to establish the location of problem areas; aerial photos from 1918 and 1927 were scanned and printed in an unrectified format; unrectified enlargements of the 1993 aerial photos were used to project approximate locations of features found on the 1918 mosaic; comparisons of contour elevations and a review of current street elevations in certain areas were done in an attempt to determine areas of

cut and/or fill material (this was presented on an unrectified, 1993 aerial photo enlargement). These products helped TEC meet the demand for information about the site while work was being done to produce photogrammetrically controlled data.

PHOTOGRAMMETRIC ANALYSIS

The Corps' Baltimore District requested accurate geographic (x,y,z) positioning of historic features in the Spring Valley area. This information would be used to help refine search areas for planned magnetometer surveys. To accomplish this task TEC's Geographic Sciences Laboratory (GSL) used its Terrain Information Extraction System (TIES), (Desmond, 1990). The TIES uses an Image Digitizing System (IDS) to perform image scanning with high metric accuracy (+/- 2 microns root mean square error) at resolutions from 7.5 to 120 microns. After scanning, image files are transferred to another TIES component, the Digital Stereo Photogrammetric Workstation (DSPW) for photogrammetric adjustment and data generation (Miller, 1992). The DSPW was used to perform a photogrammetric bundle adjustment of the 1927, 1991 and 1993 photographs. Control for the photography was obtained through on-site surveys of photo-identifiable features.

Ground Control

Ground control was collected by TEC's Topographic Developments Laboratory, Precise Survey Branch. Points were surveyed using NAVSTAR Global Positioning System (GPS) differential static survey techniques, which uses carrier phase measurements. Three National Geodetic Survey (NGS) Second-Order control monuments were included in the overall network of points developed for the area. Twenty-three photo-identifiable points, from the 1991 and 1993 photos, were surveyed with GPS. These points consisted of manhole covers and paint stripes on the pavement. The photo points were selected, as much as possible, in the classical position areas. It was determined through a network adjustment that the control monuments used met Second-Order standards as defined in the 1984 Federal Geodetic Control Committee publication Standards and Specifications for Geodetic Control Networks. The final developed horizontal positions, in geographic coordinates, were referenced to the North American Datum of 1983 (NAD83), and the heights were referenced, in meters, to the National Geodetic Vertical Datum of 1929 (NGVD29). The final adjustment for the points had a root mean square (RMS) error of less than one foot in x, y and z.

Aerial Photo Background

The 1927 photos have an undetermined metric quality with no information on the focal length of the camera nor any type of calibration data. No calibration report would have been available for photos until sometime in the mid 1940's. The photographs of 1991 and 1993 were of good metric quality with a calibration report. Due to the size of the project area, and to some extent time constraints, it was determined that not all of the photographs received were needed for photogrammetric adjustment. Five 1927 photos, three 1991

photos, and three 1993 photos were scanned.

Scanning

The photographs of 1927, 1991 and 1993 were scanned on the IDS to obtain digital image and data files. The photos of 1927 are negatives and were scanned at a resolution of 60 microns. This resulted in file sizes of about 12 megabytes (Mb) each. This pixel resolution was sufficient due to the poor resolution and contrast of the negatives. Each photo had an opaque border plus a tick mark at the center of each side of the border. The intersection of the tick marks and the border was treated as fiducials and measured on the scanner. No camera information was present on the photo border.

The three photos of 1991 were positive transparencies taken with a metric camera at a scale of 1:14,400. They were scanned at a resolution of 15 microns in order to obtain the highest possible absolute orientation data commensurate with the high positional accuracy of the GPS-determined ground control points. These points, for the 1991 photos, were mainly walkway intersections and stripe intersections painted on the streets. These three files have a ground sample distance (GSD) of 0.2 meters. Each file is very large (because of the 15 micron pixel size), approximately 140 Mb for the two end photos and 230 Mb for the center photo.

The 1993 photos were color transparencies at a scale of 1:3,600. These were scanned at a resolution of 30 microns. This resulted in file sizes of about 58 Mb. This resolution was adequate to accurately locate and measure the ground control points, which were mainly manhole covers. Unfortunately these color transparencies did not produce good black and white images when scanned with the neutral filter. Many sun-reflected areas were saturated. Also, color photos are not considered a good photo source for producing Digital Terrain Model (DTM) data.

Data Transfer

This consisted of importing the digital images and ASCII header files from the IDS into the DSPW. The header files contain information on the image, including interior orientation data.

1927, 1991, 1993 Bundle Adjustments.

Because of metric concerns regarding the 1927 imagery, two photogrammetric block adjustments were performed. One contained photos of 1991 and 1993; another was for the 1927 photos. Numerous ground control points and pass points were used in the adjustments. The 1991-93 adjustment provided a RMS error of 0.5 meter, 0.2 meter, and 0.2 meter respectively for the x, y (positional) and height. When recovering the control points on the photo after the absolute orientation, the error was in the order of 0.1 to 0.2 meter RMS for both position and height.

Control from the 1991-93 photo block was passed to the 1927 photo block. Because of the extreme temporal changes that have happened in this area of Washington, D.C. over 66

years, the selection of common points (i.e., points existing in 1927 that remained the same through 1991 and 1993) was a serious problem. Road intersections, building corners and two trees were used to pass control from the 1990's to the 1920's. Numerous pass points were used.

Despite extensive research the actual focal length of the camera used in 1927 was unknown. Experimental calculations using measured radial lens distortion within the imagery yielded unprobable answers. A flying height and focal length relationship was chosen that gave an accurate scale calculation for the block adjustment. An opaque border (measuring approximately 210 mm by 161 mm) containing tick marks on each of the four sides was present on each of the 1927 images. It was hoped that this could be used to adjust the interior orientation. However, no documentation was found to establish the original distances of this opaque border with tick marks (only a nominal photo size was found of 7"x9"). Due to the unknown camera parameters the final block adjustment did not model the interior orientation. It provided an RMS error of 2.6 meter, 1.7 meter and 4.6 meter respectively for x, y and z. The poor solution in z prohibited any reliable elevation related analysis (such as cut and fill of soils) from being made during this investigation. This solution is considerably worse than the 1991-93 image block solution. This can likely be explained by the unknown focal length, unknown lens distortion, poor lens quality of the 1927 camera, lack of ability to quantify the 66 years of film distortion, temporal aspects within the 1927 photos, and the difficulty in finding an adequate number and good distribution of ground control points.

DIGITAL FEATURE MAPPING

Mapping of historical features was done using feature extraction tools on the DSPW. Since the 1927 photos showed only some relic features existing from 1918 to 1927, the majority of features were manually transferred from the 1918 mosaic to the digital 1927 image. This method involves the photo interpreter's skill in placing the historical feature onto the 1927 image.

The former chemical munitions testing area was returned to a rural landscape but physical features (such as trees, trails, roads and buildings) from 1918 still were present in 1927. This evidence was primary for the placement of the 1918 features onto the 1927 landscape. However, some 1918 features did remain as was evident from ground scarring, moisture differences and vegetation differences. These "remaining" features were of primary concern to the Corps of Engineers. The positional accuracy of these "remaining" features are greater than those that were manually placed. Manually placed features are located based on their position/orientation to physical features.

The feature mapping was done in stereo, digitizing each feature onto the perceived ground surface. Some features were mapped in mono due to a couple of stereo gaps. The elevation data for these "mono extracted" features were obtained from historical map data. The mapping of a feature

with regard to elevation is important when trying to define the "true" position of the feature.

Even though the solution for the 1927 adjustment was not as good as the 1991 or 1993 model, it provided a better fit than just rescaling disparate databases manually. With this process the error can be quantified and useful data can be provided. The positional accuracy for "remaining" features was +/- 3 meters; +/- 5 meters for manually placed features. Using the DSPW, the final feature layer was draped over the 1991 and 1993 photos to show their positions on the current landscape. Products were then made and provided to the Corps' Baltimore District.

PRODUCTS

To assist the Corps' Baltimore District, a hardcopy product that could be used in the field was requested. GSL determined that a hardcopy orthophoto would satisfy the user requirement. In addition to the hardcopy product a list of geographic coordinates for each of the digitized features was requested.

DTM Development

The first step in the creation of the digital orthophotos (after triangulation of the photos) was to extract intermediate resolution elevation data from the stereo photos. Using the 1991 photos as source material, a DTM was created over the area of interest using a post spacing of one arc second (30 meters in latitude and 24 meters in longitude). An automatic correlation technique called Hierarchical Relaxation Correlation (HRC) was used to extract the elevation data. The application of this technique has many strategies available to the user that can be customized to best fit the terrain and resolution of the source imagery. We ran a couple of test strategies and picked the one which worked best for this case.

The HRC technique worked well for the majority of the area; however, some editing was required to clean up the data. One dilemma we faced was whether or not to land the dot on top of the building or ground level in order to generate orthophotos over the urban terrain. The "top of the building" method was used to generate the orthophotos. For the elevation data set, used to generate the contours, "the ground" method was selected. The HRC technique can be adjusted to perform either method, however, for this job we used the editing functions to put the dot on the ground or on top of the buildings.

Digital Orthophoto Generation

Four orthophotos were then generated. The input used for these orthos were the elevation data and two of the 1991 photos with a pixel resolution of 0.2 meters. The orthophotos were downsampled to a pixel resolution of 0.4 meters for output. This was done to reduce the size of the images because the output printer format was limited to 17 inches in width.

The photogrammetric workstation has an option to "burn"

feature data, contours and grids onto output images. This option was used to depict the relevant historic features onto the current date images. Contours at an interval of ten feet and a geographic grid (NAD83 horizontal datum) with a spacing of five arc seconds were also burned into the orthophotos at this point.

The digital orthophotos were then exported to a Personal Computer (PC) where additional annotation was done to label the features, contours and grids, as well as insert a legend on the border. This PC also served as the digital interface to a large format high resolution plotter that was used to make the final output of the orthophotos. The plotter output the images at a resolution of 2,000 dots per inch. The scale of the output images was 1:2,652. An orthophoto for one of the 1993 images was also produced at the same scale. An example of the product is shown in Figure 4.

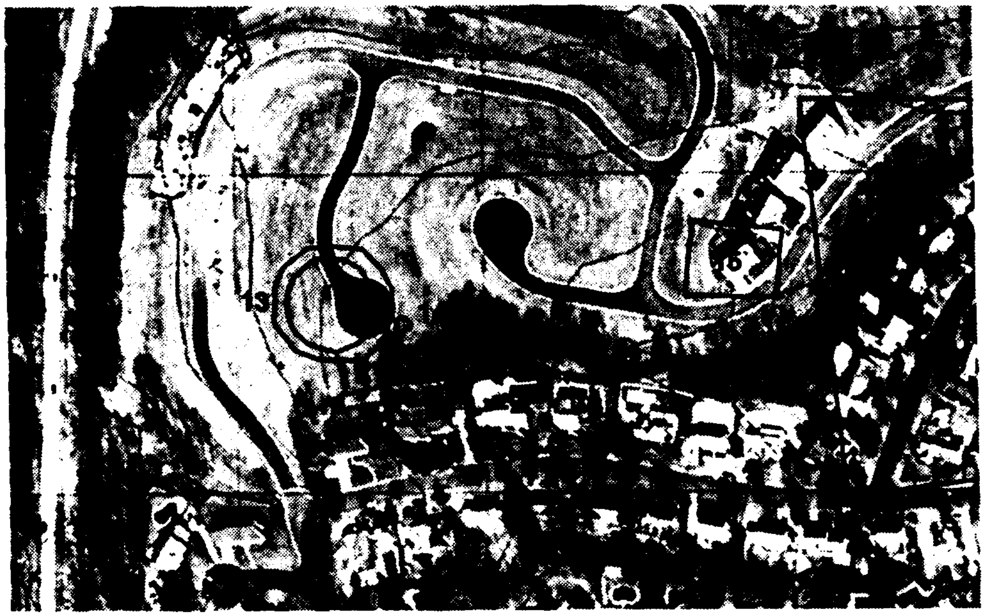

Figure 4. Portion of 1991 Orthophoto over Spring Valley.

<u>X, Y, and Z data</u>
A coordinate dump for each feature was provided to the user in ASCII format. This data was to be used in a Geographic Information System (GIS) being developed for the area.

CONCLUSION

The value of taking on a project such as this one is often realized some time after its conclusion. Valuable sources were searched for historical data. These varied sources will no doubt be significant to future historical photo analyses. In addition other sources were not searched thoroughly or not at all due to time constraints for the production of data. This is always a factor.

It was found that the triangulation of large scale photography (1:3,600) for a relatively large area is to costly, time consuming and requires large digital storage

capacities. The scale of 1:14,400 was ideal for this work. Color photography did not prove to be of any advantage for this work; black and white provided better tone and contrast.

The selection of control points due to temporal changes can be difficult. One needs to be concerned with such differences in features as the modification of a structure over time (an added level to a house for example). The presence of urban structures presents additional problems for the generation of DTM. This can be accounted for through the testing of correlation strategies.

The final output was able to be quantified. However, due to the lack of physical evidence available on the 1927 photos, certain features could not be located as accurately as others. Also the poor "z" or height in the 1927 solution did not make the product useful for cut and fill analysis. However the x,y positioning of the features was useful in that it provided a more accurate placement of historical features on the current landscape of the Spring Valley area.

ACKNOWLEDGMENTS

The authors wish to thank all of the organizations and individuals, private and government, who contributed to this project and the paper. Cooperation between government agencies and with the private sector enabled the Corps of Engineers and the Topographic Engineering Center to perform its mission and produce tangible results.

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